PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-002064

(43)Date of publication of application : 11.01.1994

(51)Int.Cl. C22C 21/02
C22F 1/05

(21)Application number : 04-221877

(22)Date of filing : 15.06.1992

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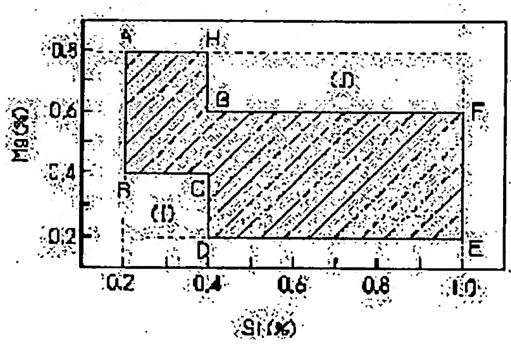
(54) HIGH-STRENGTH AND HIGH-FORMABILITY AL-MG-SI ALLOY AND ITS MANUFACTURE

(57)Abstract:

PURPOSE: To economically manufacture the objective high strength and high formability Al-Mg-Si alloy by specifying the compsn. constituted of Mg, Si, Cu, Mn, Cr, Zr, Ti and Al and executing specified heat treatment.

CONSTITUTION: An Al alloy contg., as essential components, by weight, 0.2 to 0.8% Mg 0.2 to 1.0% Si and 0.1 to 0.4% Cu by the amounts within the region surrounded by lines connecting A (0.2, 0.8), B (0.2, 0.4), C (0.4, 0.4), D (0.4, 0.2), E (1.0, 0.2), F (1.0, 0.6), G (0.4, 0.6) and H (0.4, 0.8) in Si-Mg diagram and furthermore contg. at least one kind among 0.1 to 0.8% Mn, 0.1 to 0.4% Cr, 0.05 to 0.2% Zr and 0.005 to 0.2% Ti, and the balance Al with inevitable impurities is subjected to hot or cold rolling to regulate its thickness into a prescribed one. After that, this alloy sheet is heated to 475 to 550°C at ≥100°C/hr, is thereafter cooled to 45 to 65°C at 100°C/min and is furthermore held at ≥80°C for 15min to 12hr or at ≥70°C for 15min to 10hr.



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[Date of request for examination]

[Date of sending the examiner's decision of rejection]

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CLAIMS

[Claim(s)]

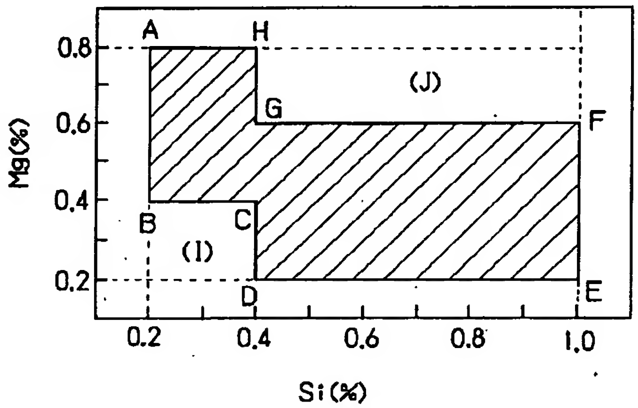
[Claim 1] By weight %, as the (hereafter same) indispensable component at Mg:0.2-0.8%, Si:0.2-1.0%, and Cu:0.1-0.4% and the A point (Si:0.2%, Mg:0.8%) shown in <u>drawing 1</u> and a B point (Si: -- 0.2%) Mg:0.4% and C point (Si:0.4%, Mg:0.4%) and D point (Si: -- 0.4%) Mg:0.2%, E points (Si:1.0%, Mg:0.2%), and F points (Si: -- 1.0%) Mg:0.6%, G points (Si:0.4%, Mg:0.6%), and H points (Si: -- 0.4%) Mg and Si are contained in the amount in the field of the line which connected Mg:0.8% one by one. Furthermore, the high intensity high moldability aluminum-Mg-Si system alloy characterized by containing at least one of Mn:0.1-0.8%, Cr:0.1-0.4%, Zr:0.05-0.2%, and Ti:0.005-0.2% of sorts, and the remainder consisting of aluminum and an unescapable impurity.

[Claim 2] Hot rolling or cold rolling is performed about aluminum alloy which has a chemical entity according to claim 1. After adjusting to predetermined product thickness, it heats at 475-550 degrees C with the heating rate 100 degrees C / more than hr. Then, it supplies with the cooling rate 100 degrees C / more than min in 45-degree-C or more warm water 65 degrees C or less. The manufacture approach of the high intensity high moldability aluminum-Mg-Si system alloy which carries out a reclosing into warm water 80 more degrees C or more, and is characterized by holding 15 minutes or more for 12 or less hours, or supplying in warm water 70 degrees C or more, and holding 15 minutes or more for 10 or less hours.

[Claim 3] The manufacture approach of the high intensity high moldability aluminum-Mg-Si system alloy characterized by performing short-time heating of 10 or less hours 5 minutes or more at 150-250 degrees C about the alloy obtained by claim 2 after performing 10 more% or more of cold working.

[Translation done.]

Drawing selection Representative drawing



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* NOTICES *

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to a high intensity high moldability aluminum-Mg-Si system alloy and its manufacture approach.
[0002]
[Description of the Prior Art] Conventionally, as an aluminum alloy for fabricating operations, the aluminum-Mg system alloy (5000 systems) of non-heat-treating molds, such as 5052 which is excellent in workability and corrosion resistance with inside reinforcement, and 5083, has been used. However, the demand of lightweight-izing is still severer and the aluminum alloy of a high moldability is strongly called for with the high intensity replaced with these 5000 system alloy.
[0003] Although there is a heat treatment mold alloy of 2000 systems, 6000 systems, and 7000 systems as a high intensity aluminum alloy, a moldability is inferior, or since heat treatment is required, there are problems, like a manufacturing cost is high.
[0004] Moreover, in order that a 5000 system alloy may prevent stress corrosion cracking with the ingredient which contains that reinforcement falls and Mg so much when used in the elevated-temperature ambient atmospheres at the time of automobile transit etc., it is pointed out as an improving point that an activity at temperature higher than 66 degrees C is regulated etc.
[0005] This invention aims at offering the new aluminum alloy with which high intensity equivalent to heat treatment mold alloy 6061-T6 is obtained, and offering the manufacture approach, having a moldability equivalent to the high moldability aluminum alloy 5052, in order to meet these demands.
[0006]
[Means for Solving the Problem] In order to solve said technical problem, this invention person used to complete this invention here, as a result of repeating research in the quality-governing list from which high intensity equivalent to the heat treatment mold aluminum alloy of high intensity is obtained by short-time heat treatment like the conventional non-heat-treating mold aluminum alloy wholeheartedly about manufacture conditions.
[0007] Namely, this inventions are Mg:0.2-0.8%, Si:0.2-1.0%, and Cu:0.1-0.4% as an indispensable component. and the A point (Si:0.2%, Mg:0.8%) shown in drawing 1 and a B point (Si: -- 0.2%) Mg:0.4% and C point (Si:0.4%, Mg:0.4%) and D point (Si: -- 0.4%) Mg:0.2%, E points (Si:1.0%, Mg:0.2%), and F points (Si: -- 1.0%) Mg:0.6%, G points (Si:0.4%, Mg:0.6%), and H points (Si: -- 0.4%) Mg and Si are contained in the amount in the field of the line which connected Mg:0.8% one by one. Furthermore, at least one of Mn:0.1-0.8%, Cr:0.1-0.4%, Zr:0.05-0.2%, and Ti:0.005-0.2% of sorts is contained. Let the high intensity high moldability aluminum-Mg-Si system alloy characterized by the remainder consisting of aluminum and an unescapable impurity be a summary.
[0008] Moreover, the manufacture approach performs hot rolling or cold rolling about aluminum alloy which has the above-mentioned chemical entity. After adjusting to predetermined product thickness, it heats at 475-550 degrees C with the heating rate 100 degrees C / more than hr. Then, it supplies with the cooling rate 100 degrees C / more than min in 45-degree-C or more warm water 65 degrees C or less. Carry out a reclosing into warm water 80 more degrees C or more, and hold 15 minutes or more for 12 or less hours, or supply in warm water 70 degrees C or more, and it holds 15 minutes or more for 10 or less hours. After performing 10 more% or more of cold working if needed, it is characterized by performing short-time heating of 10 or less hours 5 minutes or more at 150-250 degrees C.
[0009] This invention is explained further below at a detail.
[Function]
[0010] Generally the processing process of the conventional non-heat-treatable aluminum alloy is as follows.
- Raw material (elasticity material) -> fabricating-operation -> (it is baking finish by the product).
[0011] On the other hand, when the conventional heat treatable aluminum alloy is left in a room temperature after

solution-ized water quenching, an age-hardening will advance in several days and it is remarkably inferior in fabricating-operation nature. For this reason, generally it is processed in the state of the good elasticity material of fabricating-operation nature. Therefore, a processing process becomes as follows very long, and a manufacturing cost becomes high. And the actual condition is adopted only as the limited product which thinks a product function as important.

- raw material (elasticity material) -> fabricating-operation -> -- solution-izing -- -> water-quenching -> distortion correction ->T6 aging.

[0012] On the other hand, aluminum alloy concerning this invention gives a delayed effect by managing severely the ratio and content of Mg of a principal component, and Si, and combining heat treatment. For this reason, the raw material obtained is equipped with the high moldability, and when obtaining aluminum alloy of high intensity with this high moldability further, the reinforcement of a high intensity heat treatment mold alloy is obtained at the same process as the case where non-heat-treating mold alloys, such as 5052 and 5083, are used. The processing process applied at this time is as follows.

- A raw material (elasticity material) -> fabricating operation (10% or more) -> short-time heating (less than [more than 150-250 degree-Cx5 minute 10 hour]).

[0013] First, the reason for definition of the chemical entity of the aluminum-Mg-Si system aluminum alloy in this invention is explained.

[0014] Mg: Reinforcement is determined by the size and the consistency of Mg2Si, when the compound of Mg2Si is deposited and it obtains high intensity according to solution-izing, hardening, and T6 aging. In this invention, by managing Mg to 0.2 - 0.8%, it can have the delayed effect to which aging does not advance even if it leaves it in the room temperature after hardening, and high intensity can be obtained with short-time heating after a fabricating operation. However, a delayed effect cannot be given, if the reinforcement eventually obtained if there is less Mg than 0.2% is low and there is than 0.8%. [more] Therefore, let the amount of Mg be 0.2 - 0.8% of range.

[0015] Although Si:Si is an important element which has the same effectiveness by the same reason as Mg, a delayed effect cannot be given, if the reinforcement eventually obtained if fewer than 0.2% is low and there is than 1.0%. [more] Therefore, let the amount of Si be 0.2 - 1.0% of range.

[0016] however, the A point (Si: -- 0.2%) which the content of Mg and Si is [above-mentioned] within the limits, and is shown in <u>drawing 1</u> Mg:0.8%, a B point (Si:0.2%, Mg:0.4%), and C point (Si: -- 0.4%) Mg:0.4% and D point (Si:0.4%, Mg:0.2%) and E points (Si: -- 1.0%) Mg: It is necessary to manage 0.2% in the amount in the field of the line which connected F points (Si:1.0%, Mg:0.6%), G points (Si:0.4%, Mg:0.6%), and H points (Si:0.4%, Mg:0.8%) one by one.

[0017] That is, if it is a content within the limits of this, it will have the delayed effect to which aging does not advance even if it leaves it in the room temperature after hardening, and high intensity will be obtained by short-time heating after a fabricating operation. In addition, since the reinforcement eventually obtained in Mg:0.2-0.4% and Si:0.2-0.4% (I region of <u>drawing 1</u>) is low, it is not desirable, and in the range (J region of <u>drawing 1</u>) which is Mg:0.6-0.8% and Si:0.4-1.0%, since a delayed effect cannot be given, it is not desirable.

[0018] In forming the compound of Mg2Si, Cu:Cu works as a nucleus of a deposit, and has the effectiveness which contributes to the improvement in on the strength. However, a delayed effect cannot be given, if [than 0.4%] more [when fewer than 0.1% / there is no effectiveness in the improvement in on the strength and]. Therefore, let the amount of Cu(s) be 0.1 - 0.4% of range.

[0019] In this invention, although the above-mentioned element is used as an indispensable component, at least one sort of Mn, Cr, Zr, and Ti is further added in optimum dose so that it may explain below.

[0020] At less than 0.1%, although Mn:Mn is an element contributed to stabilization of an organization, if there is little the effectiveness and it exceeds 0.8% on the other hand, a big and rough intermetallic compound will generate and a moldability will fall. Therefore, let the amount of Mn be 0.1 - 0.8% of range.

[0021] At less than 0.1%, although Cr:Cr is an element contributed to stabilization of an organization like Mn, if there is little the effectiveness and it exceeds 0.4% on the other hand, a big and rough intermetallic compound will generate and a moldability will fall. Therefore, let the amount of Cr(s) be 0.1 - 0.4% of range.

[0022] At less than 0.05%, although it is the element which Zr:Zr contributes to stabilization of an organization similarly, if there is little the effectiveness and it exceeds 0.2% on the other hand, a big and rough intermetallic compound will generate and a moldability will fall. Therefore, let the amount of Zr be 0.05 - 0.2% of range.

[0023] At less than 0.005%, although it is the element which Ti:Ti makes cast structure detailed and is contributed to improvement in fluidity and weldability, if the effectiveness is not enough and exceeds 0.2% on the other hand, a big and rough intermetallic compound will generate and a moldability will fall. Therefore, let the amount of Ti be 0.005 - 0.2% of range.

[0024] Next, the heat treatment conditions in this invention are explained. In addition, although the object of this

invention is attained by strict management of the above-mentioned chemical entity, the engine performance improves further by performing the following heat treatments.
[0025] First, although the above-mentioned aluminum alloy performs hot working or cold working and adjusts it to predetermined product thickness with a conventional method, solution treatment is performed on condition that predetermined after that.
[0026] Solution treatment: Since an ingredient fuses selectively in the reinforcement which solution-ization does not fully take place if temperature is lower than 475 degrees C, but is obtained eventually if it is low and higher than 550 degrees C, let a solution treatment temperature be the range of 475-550 degrees C. Moreover, if the heating rate at this time is slower than 100 degrees C/hr, an organization will make it big and rough, the fabricating-operation nature of a product will deteriorate, if a cooling rate is slower than 100 degrees C / min, hardening will fully be impossible and the reinforcement of a product will become low. Therefore, a heating rate and a cooling rate are carried out to more than 100 degrees C / hr.
[0027] Furthermore, when the holding time is less than 15 minutes when the temperature of the second warm water is lower than 80 degrees C and if the temperature of the first warm water thrown in at the time of cooling is not the range which is 45-65 degrees C, the delayed effect of an ingredient is not obtained. Moreover, effectiveness is saturated even if the holding time in the inside of the second warm water exceeds 12 hours. In addition, when warm water is lower than 70 degrees C, or when performing one step of hardening, and the holding time is less than 15 minutes, effectiveness is saturated, even if the delayed effect of an ingredient is not obtained and the holding time exceeds 10 hours.
[0028] Thus, as for the raw material obtained, the high moldability more than non-heat-treating mold aluminum alloys, such as 5052 and 5053, and an EQC is obtained. Moreover, necessary reinforcement is also obtained.
[0029] In this invention, when required, still higher reinforcement is obtained by performing the next processing processing. That is, if working ratio performs short-time heating of the afterbaking attachment paint etc. 5 minutes or more at 150-250 degrees C by 10% or more in 10 or less hours when performing fabricating operations, such as press working of sheet metal, spinning, roll forming, and spinning, further, about the same very high reinforcement as 6061-T6 material will be obtained. It turns out that drawing 2 investigates the relation of the reinforcement obtained when manufacture conditions (except for the rate of cold working) change the rate of cold working into a chemical entity list about the thing of this invention within the limits, and high intensity is obtained by short-time heating at 10% or more of rates of cold working.
[0030] However, effectiveness although high intensity was obtained, when it performs 10% or more of cold working has [at least less than 10%] large working ratio. In addition, if whenever [short-time stoving temperature] has the small improvement in on the strength and exceeds 250 degrees C at less than 150 degrees C, it will become overaging and reinforcement will fall. Moreover, effectiveness saturates and is not economical, even if reinforcement with heating time sufficient in less than 5 minutes is not obtained but it heats exceeding 10 hours.
[0031] Next, the example of this invention is shown.
[0032]
[Example 1] Using aluminum alloy of the chemical entity shown in a table 1 as a test specimen, cold rolling was performed after hot rolling about the ingot of this 50mm thickness, and the ingredient of 4mm thickness was manufactured. Subsequently, the conditions shown in a table 2 using this plate were heat-treated, and the raw material was obtained.
[A table 1]

区分		合金No	アルミニウム合金の化学成分 (wt%)						
			Mg	Si	Cu	Mn	Cr	Zr	Ti
本発明合金		1	0.6	0.7	0.3	0.2	—	—	0.03
		2	0.4	0.7	0.3	—	0.15	—	0.03
		3	0.6	0.5	0.3	—	—	0.10	0.03
		4	0.6	0.9	0.3	0.2	—	—	0.03
類似合金		5	0.3	0.3	0.3	—	0.15	—	0.03
		6	0.8	0.8	0.3	—	0.15	—	0.03
		7	0.6	0.7	0.3	—	—	—	—
比較合金	6061	8	1.0	0.6	0.2	—	0.2	—	0.03
	5052	9	2.5	—	—	—	0.2	—	0.03

[A table 2]

項　目	材料の製造条件	
	本発明条件	類似条件
加熱速度	２００℃／hr	２００℃／hr
溶体化温度	５３５℃	４５０℃
冷却速度	４００℃／min	４００℃／min
１次温湯温度	５５℃	５５℃
２次温湯温度	９０℃	９０℃
〃　保持時間	４hr	４hr

In addition, about No.9 (5052 alloys), 340 degree-Cx2hr heating of the plate was carried out, and it considered as O material (elasticity material). It is a table 3 [a table 3] about the engine performance of the obtained raw material.

区分	合金No.	機械的性質（４mmt）									
		成形性	素材性能			製品性能			高温加熱後の強度		
			強度			強度			強度		
		Er (mm)	σ_B (N/mm^2)	$\sigma_{0.2}$ (N/mm^2)	δ (%)	σ_B (N/mm^2)	$\sigma_{0.2}$ (N/mm^2)	δ (%)	σ_B (N/mm^2)	$\sigma_{0.2}$ (N/mm^2)	δ (%)
本発明例	１	１５	１８６	７８	３２	３１５	２９５	１７	３０６	２９７	１６
	２	１４	１８２	７２	３３	３１８	２９０	１８	３０８	２９０	１７
	３	１５	１８５	８０	３１	３１０	２９３	１７	３０９	２９４	１７
	４	１５	１８３	７８	３２	３１６	２９７	１８	３０７	２９７	１７
比較例	５	１０	２１６	１２３	２５	２５１	２０１	１６	２６２	２１２	１４
	６	１１	２１８	１３０	２４	２５１	２１２	１６	２６３	２１７	１５
	７	１１	２１７	１２９	２６	２５９	２０１	１５	２５９	２１２	１６
	１	１０	２３１	１１６	２７	２５１	２１５	１６	２６２	２１９	１４
	８	８	２４４	１２５	２５						
	９	１５	１９０	８２	２８						

（注１）Ｅｒ：エリクセン値
（注２）素材性能欄の強度は、焼入れ後、室温に４月放置後の強度である。
（注３）製品性能欄の強度は、冷間加工３０％→１６０℃×１５分の焼付け塗装実施後の強度であり、高温加熱後の強度は、更にその後、１００℃×１０００時間使用した後の強度である。

It is alike and is shown. Furthermore, the reinforcement after a heating-at-high-temperature activity is also written together to a table 3 at the product-performance list after the baking finish implementation for cold-working (30% of working ratio) ->160-degree-Cx 15 minutes to a raw material.
[0033] A table 3 shows that the example of this invention has high elongation and a high Erichsen value while having about the same low reinforcement as 5052 for a raw material, and about the same fabricating-operation nature as 5052 is shown. Moreover, still higher reinforcement is obtained by the baking finish after cold working to a raw material, and it is clear that the reinforcement after a heating-at-high-temperature activity is also high.
[0034]
[Example 2] Using aluminum alloy of the chemical entity shown in a table 1 as a test specimen, cold rolling was performed after hot rolling about the ingot of this 50mm thickness, and the ingredient of 4mm thickness was manufactured. Subsequently, this plate is used and it is a table 4 [a table 4].

区分	条件No	素材の製造条件							
		加熱工程			水冷工程A			水冷工程B	
					1次温湯	2次温湯		温湯	
		速度 (℃/hr)	温度 (℃)	冷却速度 (℃/min)	温度 (℃)	温度 (℃)	保持時間	温度 (℃)	保持時間
本発明条件	①	200	535	400	55	90	4hr	—	—
	②	150	510	250	50	85	2hr	—	—
	③	200	535	400	—	—	—	80	4hr
類似条件	④	45	535	400	55	90	4hr	—	—
	⑤	200	450	400	55	90	4hr	—	—
	⑥	200	535	400	20	65	4hr	—	—
	⑦	200	535	400	55	90	5min	—	—
	⑧	200	535	400	—	—	—	50	4hr

It is alike, the shown conditions are heat-treated, a raw material is manufactured, and, subsequently it is a table 5 [a table 5].

区　分	条件No	製品の製造条件		
		冷間加工率 (%)	加熱工程	
			温度 (℃)	保持時間
本発明条件	イ	２０	１８０	２hr
	ロ	５０	２２０	３０min
類似条件	ハ	５	１８０	２hr
	ニ	２０	１００	２hr
	ホ	２０	１００	２min

It was alike, processing and short-time heat treatment were performed on the shown conditions, and the product was manufactured. Product performance and the reinforcement after an elevated-temperature activity are shown in a table 6 at the engine-performance list of the obtained raw material.
[A table 6]

区分	合金 No	製造条件 素材	製造条件 製品	成形性 Er (mm)	素材性能 強度 σ B (N/mm²)	素材性能 強度 σ 0.2 (N/mm²)	素材性能 δ (%)	製品性能 強度 σ B (N/mm²)	製品性能 強度 σ 0.2 (N/mm²)	製品性能 δ (%)	高温加熱後の強度 強度 σ B (N/mm²)	高温加熱後の強度 強度 σ 0.2 (N/mm²)	高温加熱後の強度 δ (%)
本発明例	1	①	イ	15	186	78	32	315	295	17	306	297	17
	1	②	イ	15	178	72	33	303	287	18	301	292	17
	1	③	イ	15	190	80	31	317	298	18	312	293	17
	1	①	ロ	15	187	79	31	308	299	17	310	292	16
	2	①	イ	14	182	72	33	318	290	18	308	290	17
	3	①	イ	15	185	80	31	310	293	17	309	294	17
	4	①	イ	15	183	78	32	316	297	18	307	297	17
比較例	1	④	イ	11	224	122	24	241	221	18	253	202	13
	1	⑤	イ	10	223	125	23	237	210	18	251	212	12
	1	⑥	イ	10	221	124	24	241	211	17	246	214	15
	1	⑦	イ	11	215	118	22	239	209	18	249	209	14
	1	⑧	イ	10	226	124	23	242	199	17	257	210	15
	1	①	ハ	15	186	78	32	212	175	17	207	215	16
	1	①	ニ	〃	〃	〃	〃	209	181	18	213	201	17
	1	①	ホ	〃	〃	〃	〃	210	176	17	205	207	16
	5	①	イ	10	216	123	25	251	201	16	262	212	14
	6	①	イ	11	218	130	24	251	212	16	263	217	15
	7	①	イ	11	217	129	26	259	201	15	259	212	16
比較例	8	8	8	8	244	125	25						
	9	9	9	15	190	82	28						

（注）表３の脚注を参照。

[0035] As the example of this invention shows a table 6, while adjusting a chemical entity, although it has a high moldability, especially as for the raw material obtained by performing solution treatment, by performing further predetermined cold working and short-time heat treatment shows that high intensity can be given further. Moreover, it is shown that high reinforcement is especially maintainable with the activity in an elevated temperature.

[0036]

[Effect of the Invention] As explained in full detail above, according to this invention, having a moldability equivalent to the high moldability aluminum alloy 5052, the high intensity high moldability aluminum alloy which has high intensity equivalent to heat treatment mold alloy 6061-T6 can be offered, and there is no lowering on the strength by the activity in an elevated temperature especially. Moreover, since it can manufacture at the same process as a non-heat-treatable aluminum alloy, it is economical, and the effectiveness which contributes to amplification of an application is large.